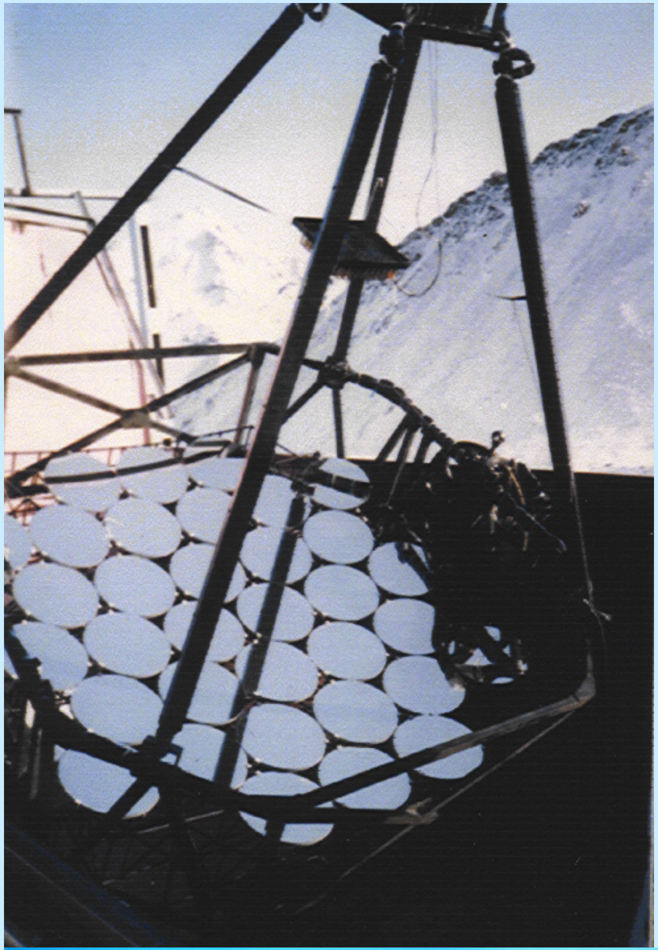


VERY-HIGH ENERGY GAMMA-RAY ASTRONOMY of GALACTIC and EXTRA-GALACTIC SOURCES by SHALON

V.G. SINITSYNA and V.Y. SINITSYNA

P. N. Lebedev Physical Institute,
Leninsky prospect 53, Moscow, 119991 Russia

VERY-HIGH ENERGY GAMMA-RAY ASTRONOMY of GALACTIC and EXTRA-GALACTIC SOURCES by SHALON

The development of the atmospheric Cherenkov imaging technique has led to significant advances in gamma-ray detection sensitivity in the energy range from 800 GeV to 100 TeV. The SHALON Observatory [1] telescope has detected the galactic and extragalactic sources in the Northern Hemisphere. Cherenkov technique operates in an energy regime where the physics of particle interactions is relatively well understood and where there exist advanced Monte Carlo programs for the simulation of particle cascades. The urgent advances in technique used in VHE gamma-ray astronomy is the development of the atmospheric Cherenkov imaging technique, which led to the efficient rejection of the hadronic background and then to detection of gamma-ray sources and their spectra.

The SHALON Cherenkov gamma-telescope located at 3340 m a.s.l., at the Tien Shan high-mountain observatory of Lebedev Physical Institute, has been developed for gamma - astronomical observation in the energy range 0,8-100 TeV. The gamma – astronomical researches are carrying out with SHALON since 1992. During the period 1992 - 2010 SHALON has been used for observations of metagalactic sources: Mkn 421, Mkn 501, NGC 1275, SN2006gy, 3c454.3, 1739+522 and galactic sources: Crab Nebula, Cyg X-3, Tycho's SNR, Geminga, 2129+47XR.

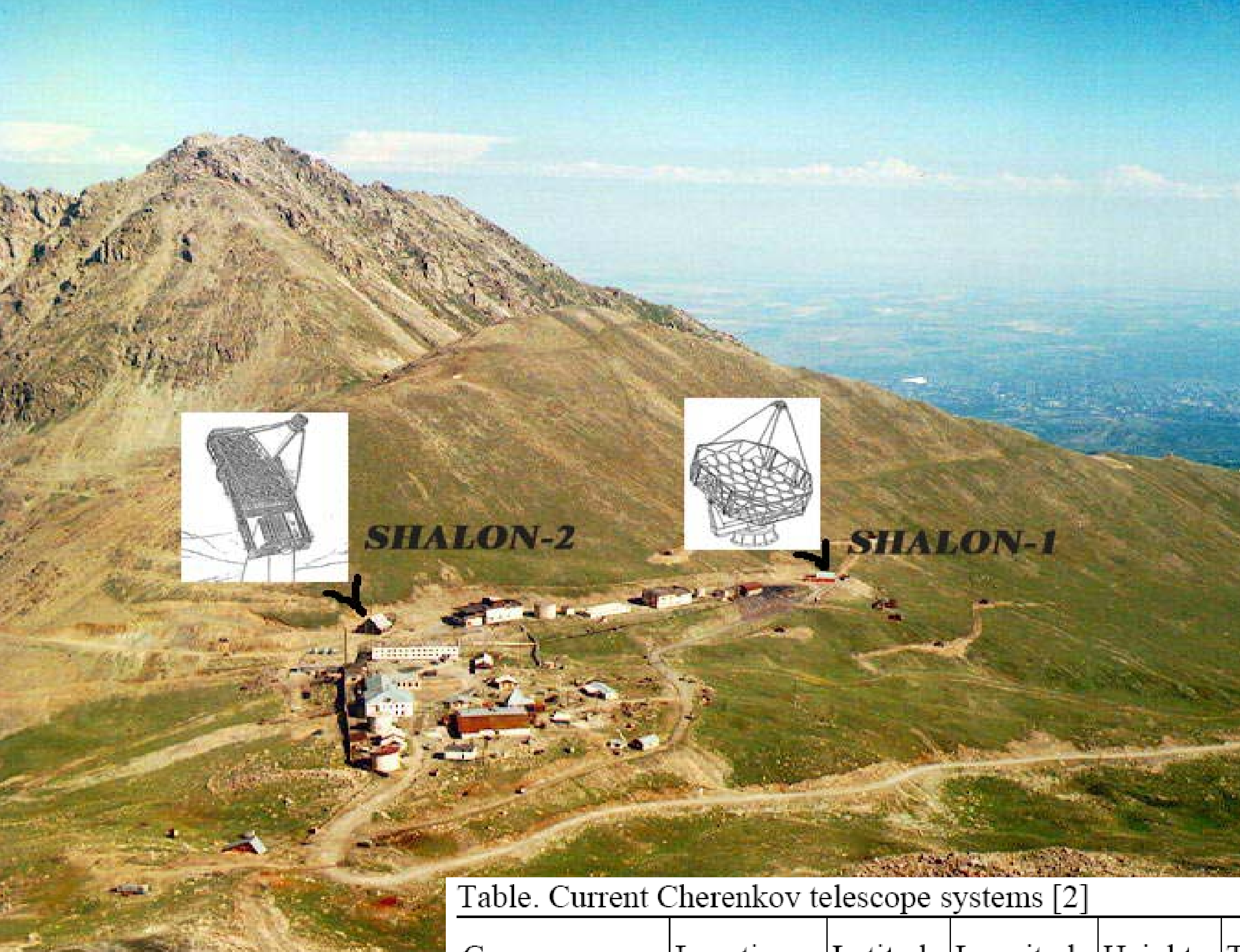
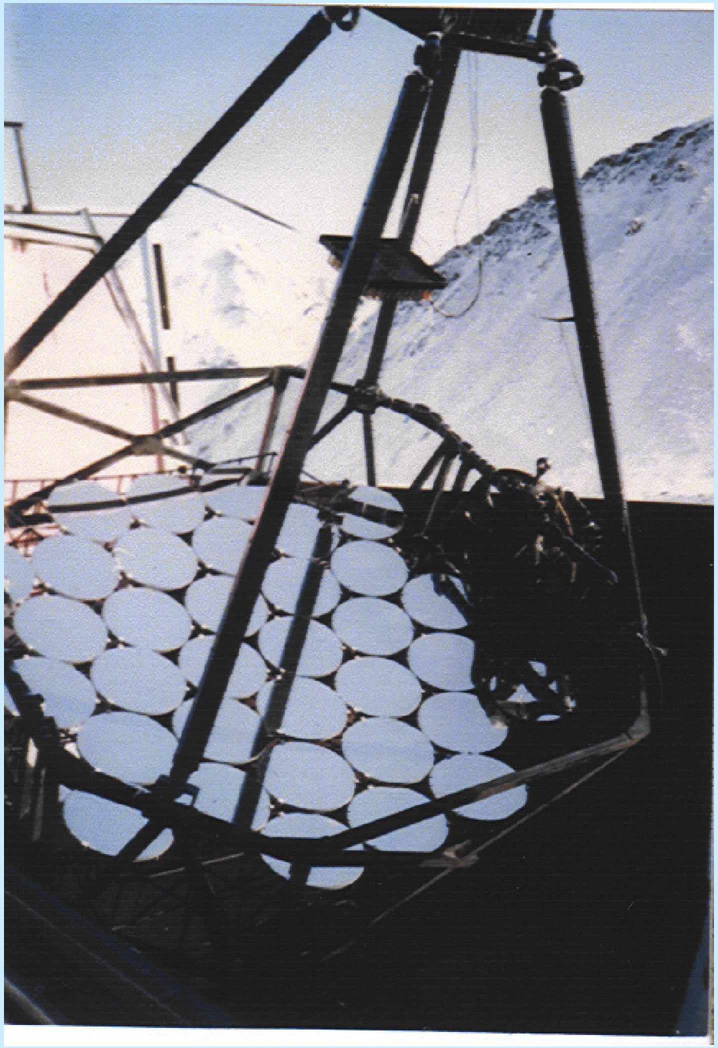


Table. Current Cherenkov telescope systems [2]

Group	Location	Latitude	Longitude	Height	Telescopes	Threshold (TeV)	Start
SHALON	Russia	43°N	77°E	3340 m	$11{,}2\ m^2\times2$	0,8	1992
TACTIC	India	25°N	73°E	1300 m	$9{,}5\ m^2\times4$	1	2000
CANGAROO	Australia	31°S	137°E	160 m	$57\ m^2\times4$	0,2	2004
HESS	Namibia	23°S	16,5°E	1800 m	$107\ m^2\times4$	0,1	2004
MAGIC	Canary Is.	29°N	18°W	2200 m	$237\ m^2\times1$	0,07	2004
VERITAS	Arisona	32°N	111°W	1268 m	$110\ m^2\times4$	0,1	2007

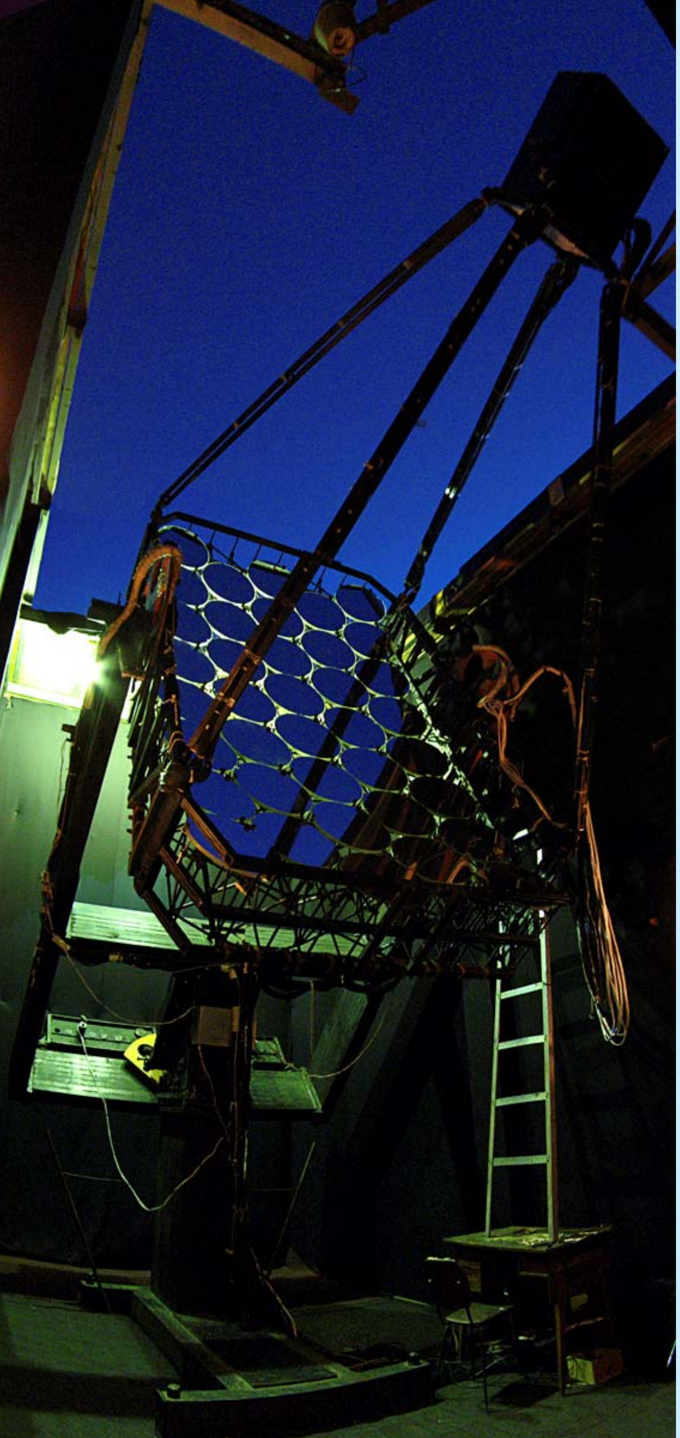
HIGH MOUNTAINOUS OBSERVATORY SHALON ALATOO

SHALON mirror Cherenkov telescope created at Lebedev Physical Institute and stated in 1991 - 1992



- Total area of spherical mirror — 11.2 m^2
- Radius of mirror curvature — 8.5 m
- The angle range of telescope turn:
- – azimuth — 0^o-360^o
- – zenith — 0^o-110^o
- The accurace of telescopic axis pointing — $\leq 0.1^o$
- The photomultiplier tube camera (12x12) — 144 elements
- Field of view $> 8^o$
- Weigth 6 ton
- altazimuth mounting

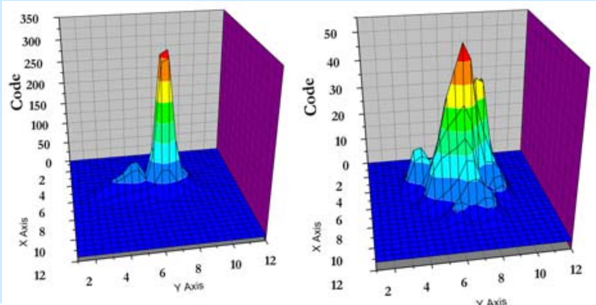
It is essential that our telescope has a large matrix with full angle $>8^o$ that allows us to perform observations of the supposed astronomical source (ON data) and background from extensive air showers (EAS) induced by cosmic ray (OFF data) simultaneously. Thus, the OFF data are collecting for exactly the same atmospheric thickness, transparency and other experimental conditions as the ON data.

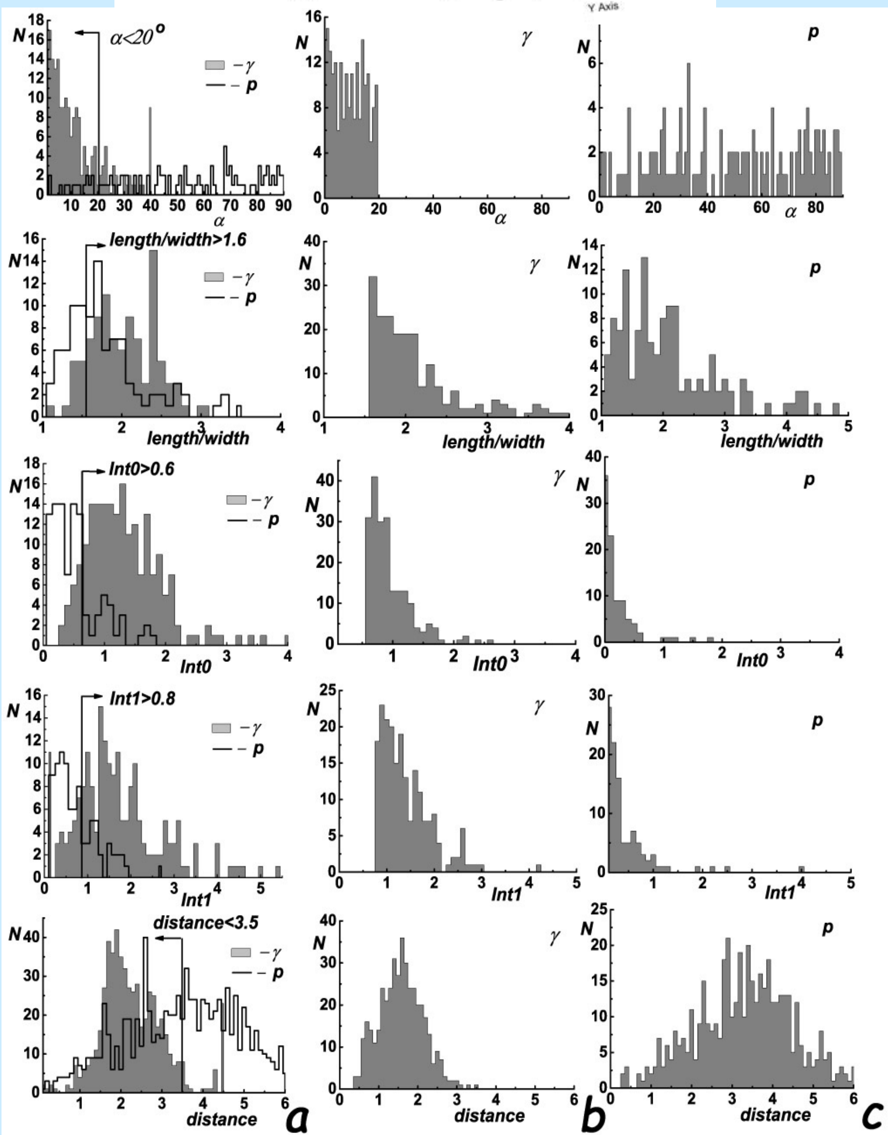


HIGH MOUNTAINOUS OBSERVATORY SHALON ALATOO

SHALON mirror Cherenkov telescope created at Lebedev Physical Institute and stated in 1991 - 1992

- Total area of spherical mirror — 11.2 m^2
- Radius of mirror curvature — 8.5 m
- The angle range of telescope turn:
  – azimuth — 0^o-360^o
  – zenith — 0^o-110^o
- The accuracy of telescopic axis pointing — $\leq 0.1^o$
- The photomultiplier tube camera (12x12) — 144 elements
- Field of view > 8^o
- Weigth 6 ton
- parallactic mount





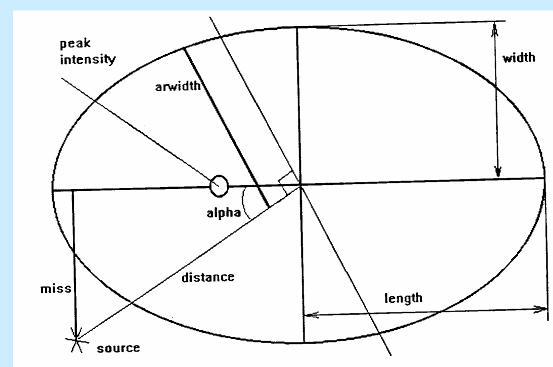
Criteria

The selection of gamma-initiated showers from the background of proton showers is performed by applying the following criteria:

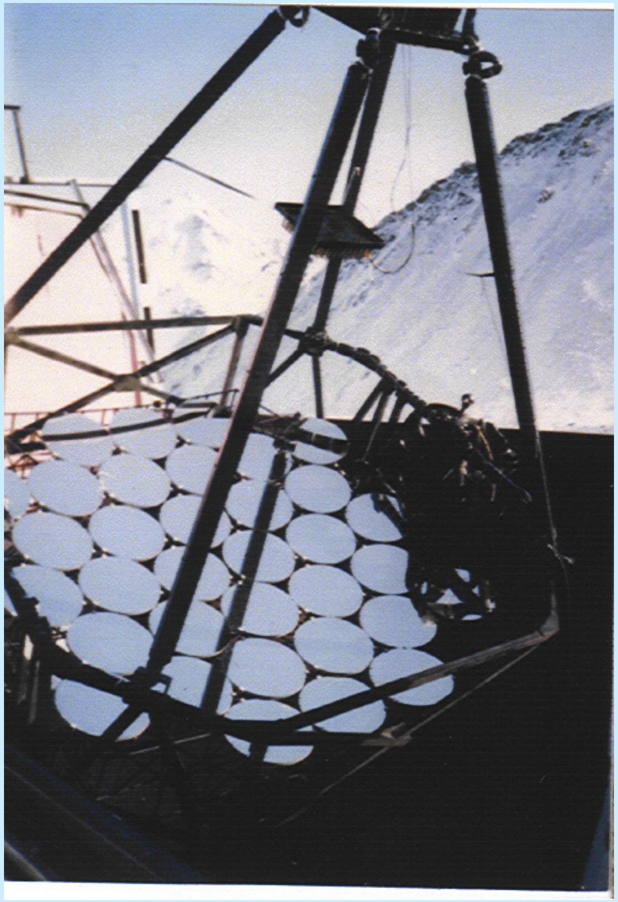
1) **$\alpha < 20^{o}$**;
2) **length/width > 1.6**;
3) the ratio **INT0** of Cherenkov light intensity in pixel with maximum pulse amplitude to the light intensity in the eight surrounding pixels exceeds **> 0.6**;
4) the ratio **INT1** of Cherenkov light intensity in pixel with maximum pulse amplitude to the light intensity in the in all the pixels except for the nine in the center of the matrix is exceeds **> 0.8**;
5) **distance** is less than **3.5** pixels.

It is essential that our telescope has a large matrix with full angle $>8^{o}$ that allows us to perform observations of the supposed astronomical source (ON data) and background from extensive air showers (EAS) induced by cosmic ray (OFF data) simultaneously.

Using these criteria the background is rejected with 99.92% efficiency, whereas gamma's rejection is no more than 35% (that is taking into account) and the amount of background gamma-like events is less than 10%.



TeV GAMMA-RAY EMISSION from GALACTIC SOURCES



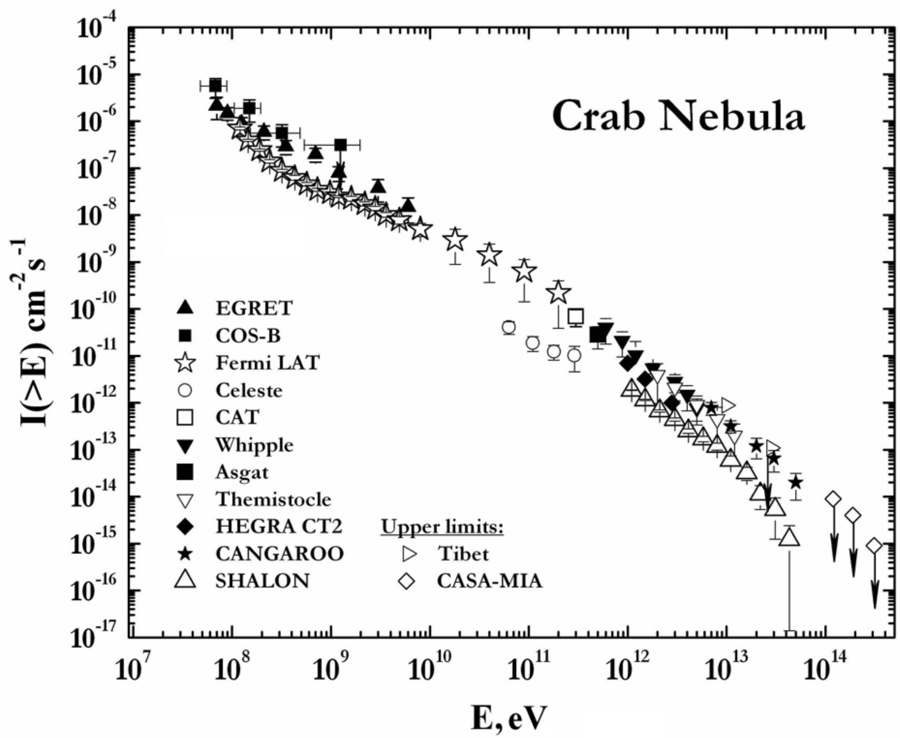
The gamma-ray sources form a new class of high-energy objects in the Universe, including active galactic nuclei, radio galaxies, galactic binaries, pulsar wind nebulae, in addition to supernova remnants which are assumed to be the origin of cosmic rays for a long time. Exploring the emission mechanism from these objects is a big challenge in astrophysics. Non-thermal nature of emission inherently needs multiwavelength observations to study the phenomena, involving astronomers working in other wavelength.

SHALON catalogue of galactic gamma -quantum sources

Source	Observable flux, $cm^{-2}s^{-1}$	Distance, kpc
Crab Nebula	$(1.72\pm0.12)\times10^{-12}$	2.0
Cygnus X-3	$(0.68\pm0.07)\times10^{-12}$	10
Geminga	$(0.48\pm0.17)\times10^{-12}$	0.25
Tycho's SNR	$(0.42\pm0.04)\times10^{-12}$	3.1
2129+47XR	$(0.19\pm0.09)\times10^{-12}$	6.0

Crab Nebula

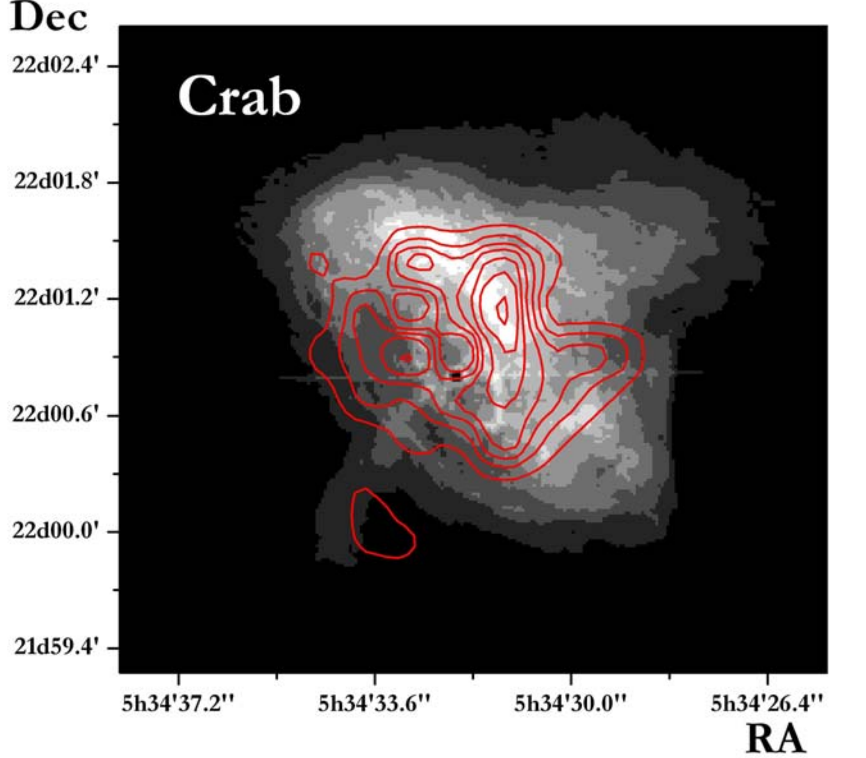
Since the first detection with ground based telescope the Crab has been observed by the number of independent groups using different methods of registration of gamma-initiated showers.



The Crab Nebula gamma-quantum integral spectrum by SHALON in comparison with other experiments.

The spectrum indices for Crab Nebula obtained by Whipple, SHALON, CANGAROO, CAT, HEGRA atmospheric Cherenkov telescopes and Tibet are presented in the table.

Group	VHE Spectrum (10^{-11} $photons\ cm^{-2}s^{-1}TeV^{-1}$)	E_{th} (TeV)
Whipple (1991)	$25 \times (E/0.4TeV)^{-2.4\pm0.3}$	0.4
Whipple (1998)	$(3.2 \pm 0.7) \times (E/TeV)^{-2.49\pm0.06_{stat}\pm0.04_{syst}}$	0.3
SHALON (2005)	$(1.7 \pm 0.12) \times 10^{-1} \times (E/TeV)^{-2.44\pm0.07}$	0.8
CANGAROO (1998)	$(2.01 \pm 0.36) \times 10^{-2} \times (E/7TeV)^{-2.53\pm0.18}$	7.0
CAT (1999)	$(2.7 \pm 0.17 \pm 0.40) \times (E/TeV)^{-2.57\pm0.14_{stat}\pm0.08_{syst}}$	0.25
HEGRA (1999)	$(2.7 \pm 0.2 \pm 0.8) \times (E/TeV)^{-2.60\pm0.05_{stat}\pm0.05_{syst}}$	0.5
Magic (2005)	$(1.5 \pm 0.18) \times 10^{-3} \times (E/GeV)^{-2.58\pm0.16}$	0.3
HESS (2005)	$(2.86 \pm 0.06 \pm 0.57) \times (E/TeV)^{-2.67\pm0.01_{stat}\pm0.1_{syst}}$ $(3.76 \pm 0.07) \times (E/TeV)^{-2.39\pm0.03_{stat} \times exp(E/(14.3\pm2.1))}$	0.44
Tibet HD (1999)	$(4.61 \pm 0.1) \times 10^{-1} \times (E/3,TeV)^{-2.62\pm0.17}$	3.0



A Chandra X-ray image of Crab Nebula.
The Crab PWN in the energy range 0.2 -4.1 keV. Image of the central 200''×200'' of the Crab Nebula. In this energy band most of the PWN X-rays come from a torus surrounding the pulsar. The red contour lines show the 0.8 – 30 TeV - structure by SHALON observations . The most part of TeV energy gamma-quanta come from the region of bright torus whereas the contribution of energy gives the region of the southern jet.

Magnetic fields and lifetimes of representative regions of Chandra image. [F. D. Seward et al.]

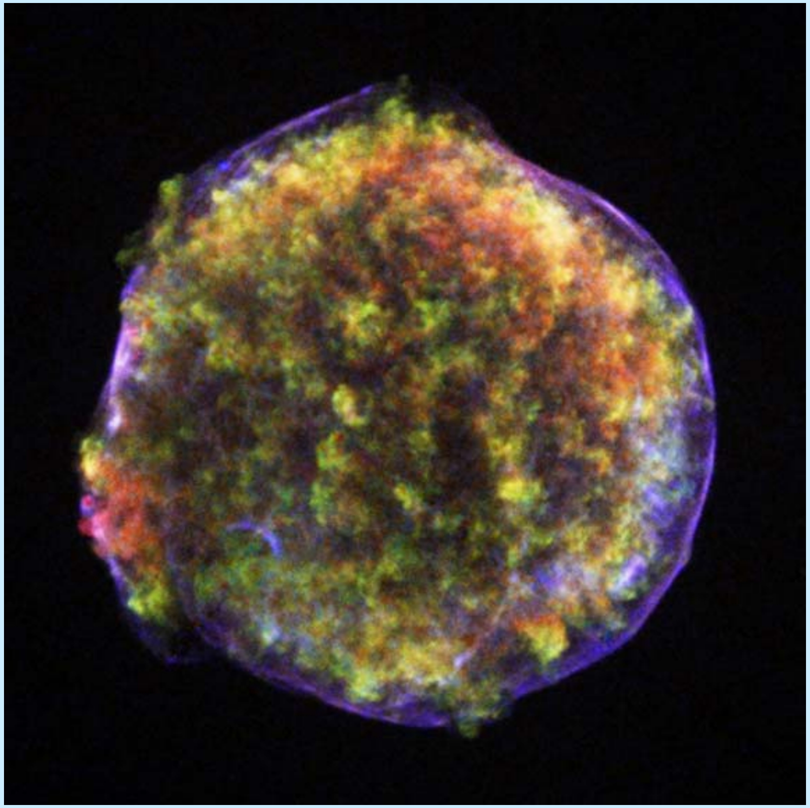
Table 3: Magnetic Fields and Lifetimes

region	field	lifetime	extent of region
	(10^{-4} Gauss)	(years)	(light years)
PWN average	5.8	6.7	1.9 (60″ radius)
bright Torus	7.7	4.3	1.7 (radius)
NW Loops	9.1	2.9	0.6
Jet center, region 7	9.1	2.9	1.8 (length of jet)
bright inner ring	10.8	2.6	0.08 (thickness of ring)
knot in bright inner ring	15.3	1.5	0.07 (size of knot)
S Finger, region 5	6.2	5.9	1.3 (length of finger)
SW Finger, region 7	6.2	5.9	1.6 (length of finger)

Additionally, we need the assuming about magnetic field strength in the region of emission.; The average magnetic field in the region of VHE gamma-ray emission is extracted from the comparison of 0.8– 30 TeV (SHALON data) and X-ray (Chandra data) emission regions.

The TeV gamma-quantum spectrum of Crab by SHALON is generated via Inverse Compton of soft, mainly optical, photons which are produced by relativistic electrons and positrons, in the nebula region around 1.5' from the pulsar with specific average magnetic field of about 67nT.

Tycho's SNR



A Chandra image of Tycho's SNR (X-ray);

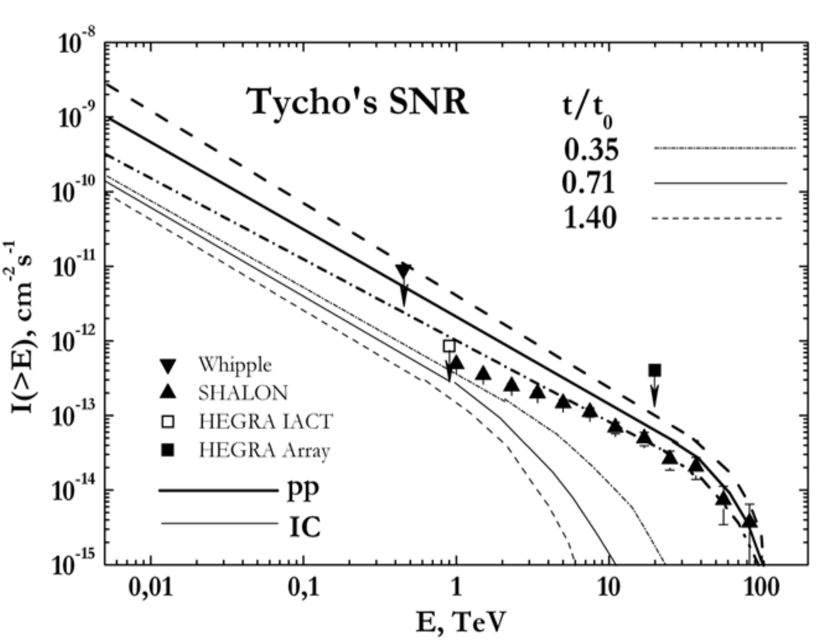
This image of the supernova remnant shows an expanding bubble of multimillion degree debris (green and red) inside a more rapidly moving shell of extremely high energy electrons (filamentary blue). The supersonic expansion of the stellar debris has created two X-ray emitting shock waves - one moving outward into the interstellar gas, and another moving back into the debris. These shock waves produce sudden, large changes in pressure and temperature.

Kinetic nonlinear theory of diffusive CR acceleration in SNRs (Berezhko, Völk) connects the gas dynamics of the explosion with the particle acceleration.

Tycho's SNR has long been considered as a candidate to cosmic ray hadrons source in Northern Hemisphere.

Tycho's SNR have been detected with SHALON mirror Cherenkov telescope at TeV region.

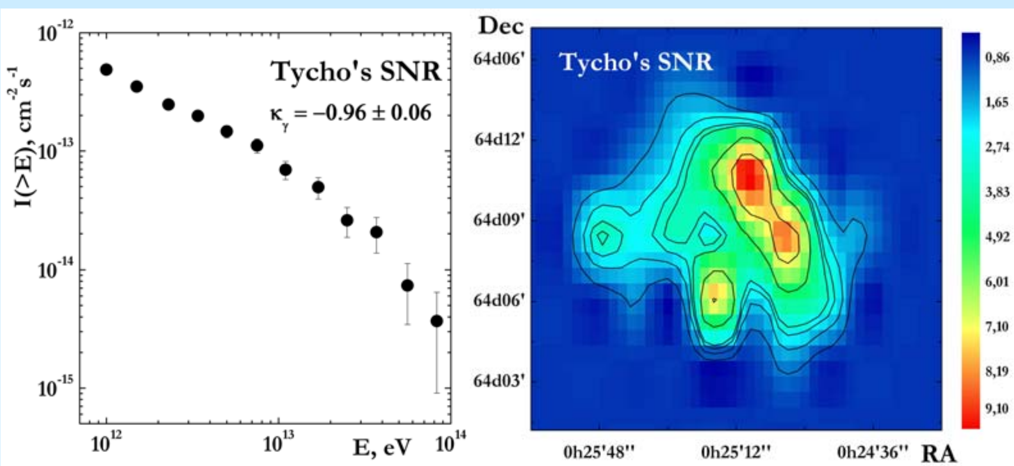
The integral gamma-ray flux above 0.8 TeV was estimated as $\mathbf{(0.52 \pm 0.09)\times10^{-12}\ cm^{-2}s^{-1}}$



The nonlinear kinetic model for cosmic ray acceleration in SNR [Berezhko, Völk] has been applied to Tycho's SNR in order to compare the model results with the recently found very low observational upper limits in the TeV energy range. In fact, HEGRA dad not detect Tycho's SNR, but established a very low upper limit at energies >1 TeV. The HEGRA' s limit is consisted with that previously published by the Whipple collaboration, being a factor 4 lower (the spectral index was assumed to be -1.1 for this comparison). The π^O - decay gamma-quantum flux turns out to be greater than the Inverse Compton flux at 1 TeV and becomes strongly dominating at 10 TeV. The predicted gamma flux is consistent with the upper limits published Whipple and HEGRA collaborations.

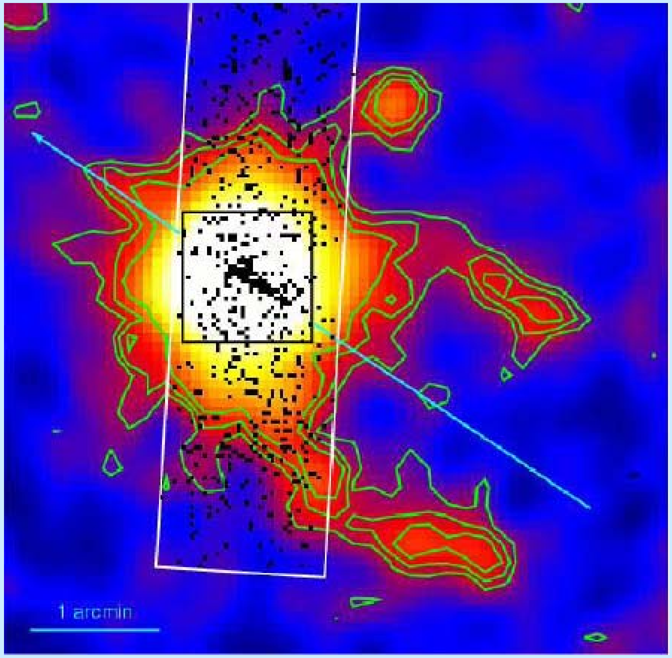
The integral average gamma-ray flux above 0.8 TeV was estimated as

$$\mathbf{I_{Tycho} = (0.52\pm0.09)\times10^{-12}\ cm^{-2}s^{-1}}$$



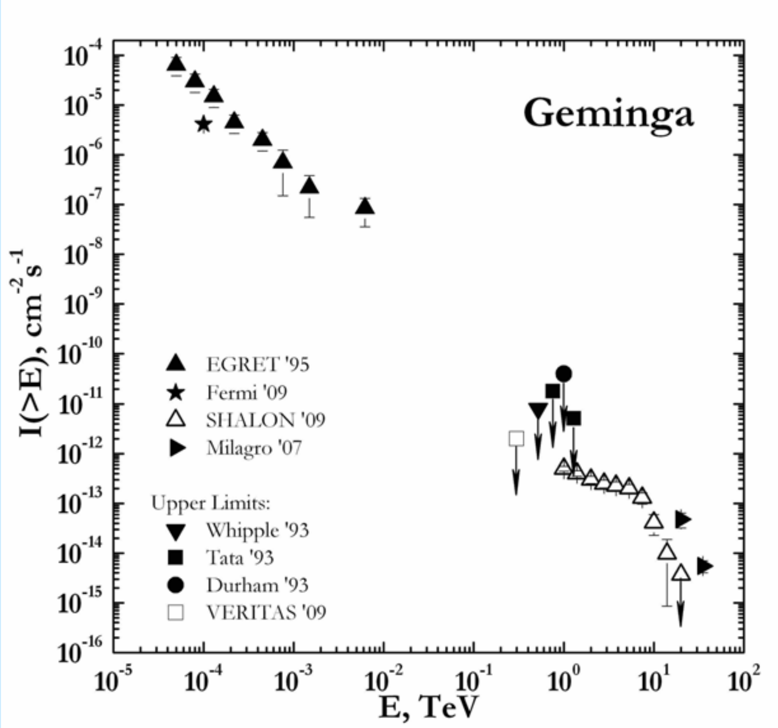
The expected π^O-decay gamma-quantum flux $F_\gamma \propto E_\gamma^{-1}$ extends up to ~80 TeV, whereas the Inverse Compton gamma-ray flux has a cutoff above the few TeV. So, the detection of gamma-rays at energies of ~ 10-80 TeV by SHALON telescope is the evidence of hadron origin.

Geminga



A neutron star in the constellation Gemini is the second brightest source of high-energy gamma-rays in the sky, discovered in 1972, by the SAS-2 satellite. For nearly 20 years, the nature of Geminga was unknown, since it didn't seem to show up at any other wavelengths. In 1991, an regular periodicity of 0.237 second was detected by the ROSAT satellite in soft X-ray emission, indicating that Geminga is almost certainly a pulsar. Geminga is the closest known pulsar to Earth; and it's the only known pulsar that is radio-quiet.

Geminga has been the object for study at TeV energies with upper limits being reported by three experiments Whipple'93, Tata'93 and Durham'93and very recently by VERITAS [1]. Also Geminga has observed with Milagro at energies of 20TeV and 35 TeV[2] and Fermi LAT at energies 30MeV - 200GeV [3]. The spectrum by Fermi is fitted with a power law with exponential cutoff in the form: $dN=dE = N0\times (E^{-\gamma})\exp(-E/E_0)$, where $N_0 = (1.19 \pm 0.08) \times 10^{-6} GeV^{-1}cm^{-2}s^{-1}$, $\gamma = 1.3 \pm 0.05$, $E_0 = (2.47\pm0.19)$ GeV . The images of gamma-ray emission from Geminga by SHALON telescope are presented. The value Geminga flux obtained by SHALON is lower than the upper limits published before. Its integral gamma-ray flux is found to be $(0.48 \pm 0.17)\times10^{-12}$ $cm^{-2}s^{-1}$ at energies of > 0.8 TeV. Within the range 0.8 - 6 TeV, the integral energy spectrum is well described by the single power law $I(>E_\gamma) \propto E_\gamma^{-0.59\pm0.10}$. The energy spectrum of supernova remnant Geminga $F(E_O > 0.8TeV) \propto E^k$ is harder than Crab spectrum.

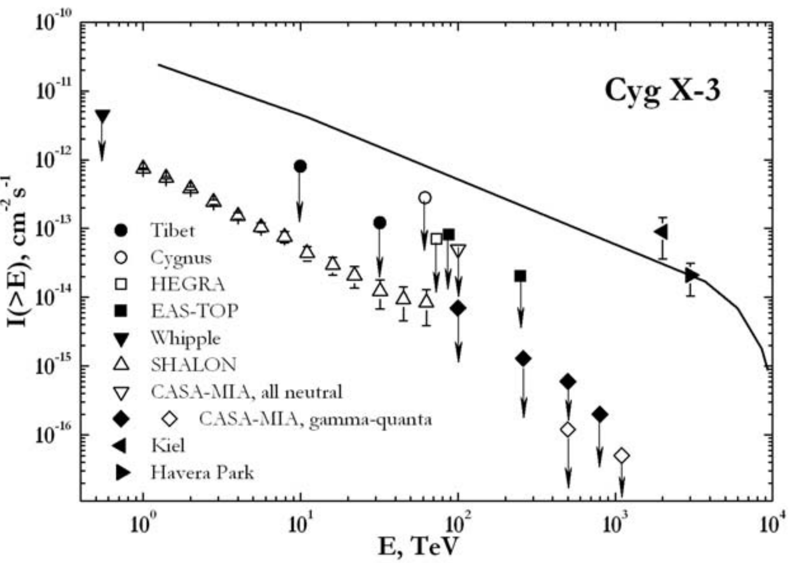


Cygnus X-3

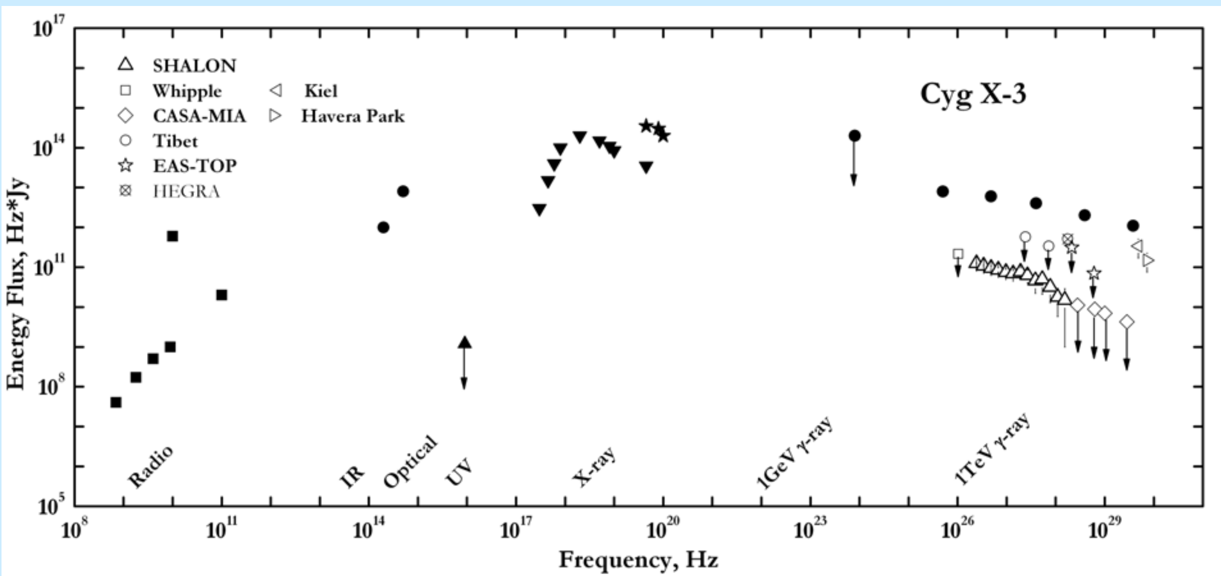
Figures collect observational data obtained with SHALON mirror Cherenkov telescope for the Cygnus X-3 point source. This galactic binary system regularly observed since a 1995 is known as a source with variable intensity (from 5×10^{-12} to 10^{-11} $cm^{-2}s^{-1}$); the average gamma-quantum flux from Cygnus X-3 for E >0.8 TeV is estimated as

$$\mathbf{F(E_O>0{,}8\ TeV)=(6.8\pm0.7)\bullet10^{-13}\ cm^{-2}s^{-1}}.$$

The standard output of the SHALON data processing consists of the integral spectrum of events coming from a source under investigation; spectrum of the background events coming simultaneously, during the observation of the source; temporal analysis of the source and background events; and the source image. The energy spectrum of Cyg X-3 at 0.8 - 65 TeV can be approximated by the power law $F(>E_O) \propto E^{k\gamma}$, with k_γ=-1.21± 0.05. This flux, measured for the first time, is several times less than the upper limits established in the earlier observations.



The Cyg X-3 gamma-quantum (*E* > 0.8 TeV) integral spectrum by SHALON in comparison with other experiments: TIBET, [7]; 2 - CYGNUS, [8, 9]; 3 - HEGRA, [10]; 4 - EAS-TOP, [11, 12]; 5 - Whipple, [13, 14]; 6 - SHALON, [16, 17]; diamonds - CASA-MIA, [15]; the solid line is the theoretical calculation (Hillas) [4, 5]. The Cyg X-3 gamma-quantum spectrum with power index of k_γ=-1.21± 0.05.



The spectral energy distribution of Cyg X-3. Black points are the archival data from Cordova, (1986). The high level points in radio and X-ray bands correspond to radio-frequency activity and increased x-ray activity of the source. TeV range is represented with integral spectrum by SHALON (open triangles) [20], [28] in comparison with other experiments: TIBET, [8] HEGRA [11], EAS-TOP [12], [13], Whipple [14], [15], CASA-MIA [16],Kiel [18], Havera Park [19]

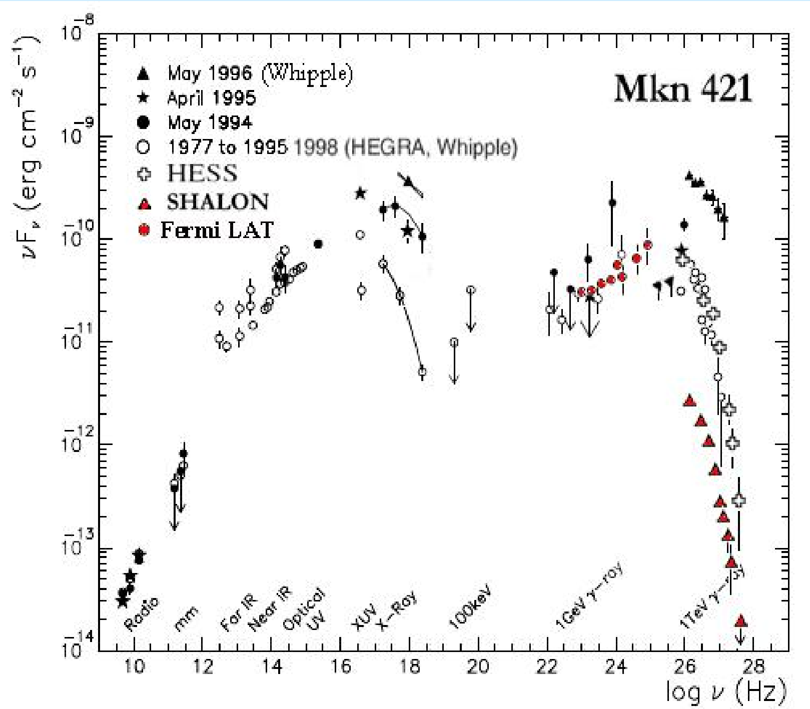
TeV GAMMA-RAY EMISSION from METAGALACTIC SOURCES

The gamma-astronomical researches are carrying out with SHALON mirror telescope at the Tien-Shan high-mountain observatory. During the period 1992 - 2010, SHALON has been used for observations of the metagalactic sources Mkn421, Mkn501, NGC1275, OJ 287, 3c454.3, 1739+522 and galactic sources Crab Nebula, Cygnus X-3, Tycho's SNR, Geminga, 2129+47XR. The SHALON results for well known metagalactic gamma-sources (Mkn 421 amd Mkn 501) are consistent with the data telescopes of Whipple, TACTIC, HESS, Magic.

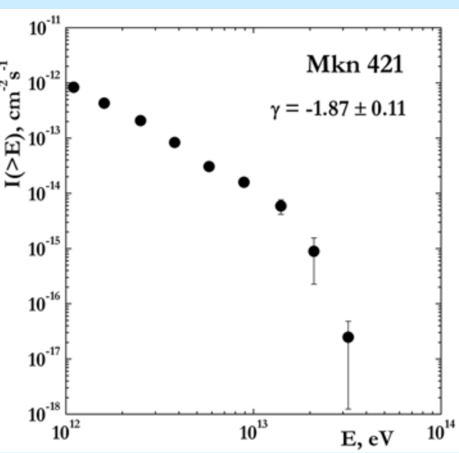
SHALON catalogue of metagalactic γ -quantum sources

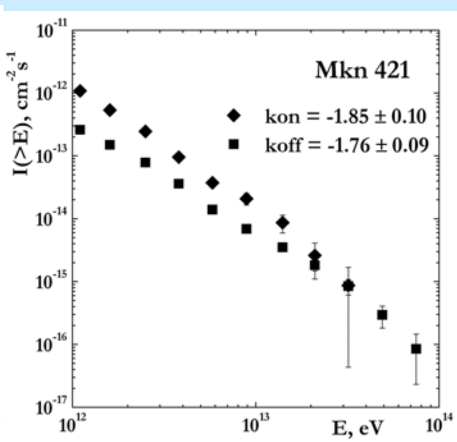
Source	Observable flux, $cm^{-2}s^{-1}$	z	Relative intensity of source (in Crab units)
Mkn 421	$(0.63\pm0.14)\times10^{-12}$	0.031	3.8×10^{9}
Mkn 501	$(0.86\pm0.13)\times10^{-12}$	0.034	4.6×10^{9}
Mkn 180	$(0.65\pm0.23)\times10^{-12}$	0.046	6.2×10^{9}
NGC 1275	$(0.78\pm0.13)\times10^{-12}$	0.0179	1.2×10^{9}
SN2006 gy	$(3.71\pm0.65)\times10^{-12}$	0.019	4.2×10^{9}
OJ 287	$(0.32\pm0.11)\times10^{-12}$	0.306	2.3×10^{8}
3c4543	$(0.43\pm0.13)\times10^{-12}$	0.859	5.3×10^{12}
1739+522	$(0.53\pm0.10)\times10^{-12}$	1.375	1.4×10^{13}

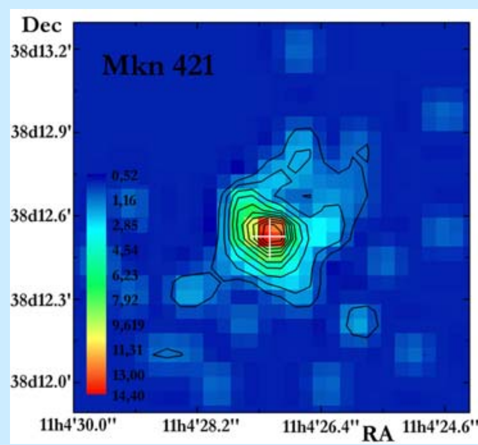
Markarian 421

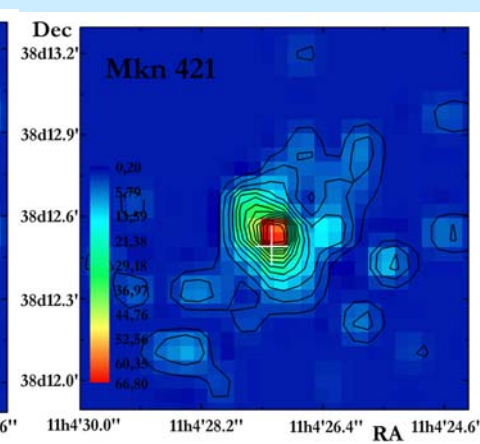


The Bl Lac Mkn 421 was detected as the first and the nearest (z = 0.031) metagalactic source of blazar type of TeV energy gamma-quanta in 1992 year using Whipple telescope. Presently this source is systematic studied by different experiments: VERITAS, SHALON, TACTIC, HESS, MAGIC. Mkn 421 is being intensively studied since 1994 by SHALON. As is seen from figure the SHALON results for this known gamma-source are consistent with the data by best world telescopes. An image of gamma-ray emission from Mkn 421 is also shown. The integral averaged for the period 1994 to 2010 gamma-ray flux above 0.8 TeV was estimated as $(0.63 \pm 0.14)\times10^{-12}$ cm^{-2}s^{-1}. Within the range 1 - 10 TeV, the integral energy spectrum is well described by the power law $F(>E_O) \propto E^{k\gamma}$, with $k_\gamma=-1.87 \pm 0.11$. Extreme variability in different wavelengths including VHE gamma rays on the time-scales from minutes to years is the most distinctive feature of BL Lac objects. The increase of the flux over the average value was detected in 1997 and 2004 observations of Mkn 421 by SHALON and estimated to be $(1.01 \pm 0.25)\times10^{-12}$ cm^{-2}s^{-1} and $(0.96 \pm 0.2)\times10^{-12}$ cm^{-2}s^{-1}, respectively. The similar variations of the flux over the average value was also observed with the telescopes of Whipple, HEGRA, TACTIC, HESS ($60^O – 67^O$), MAGIC (45^O).

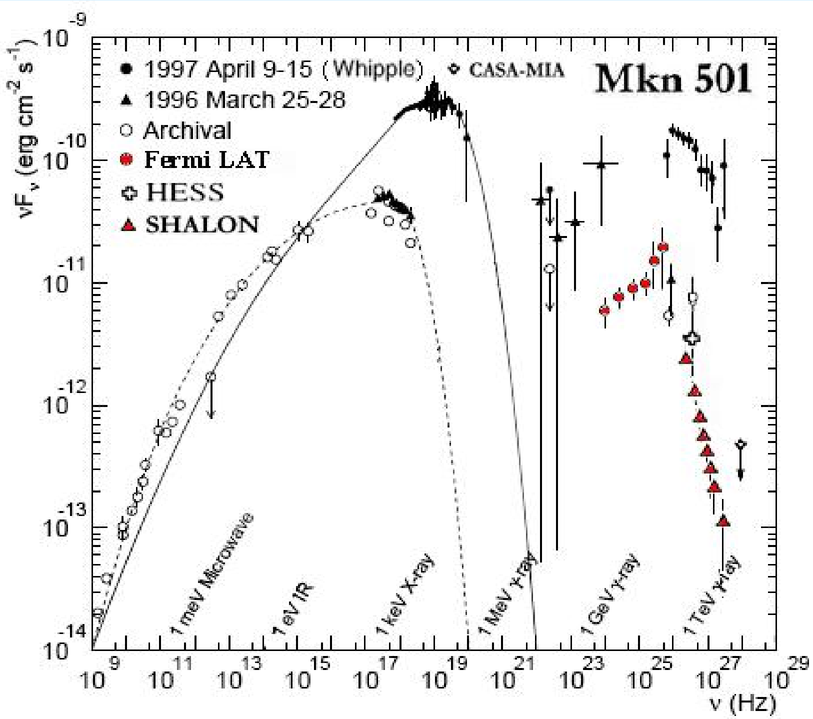




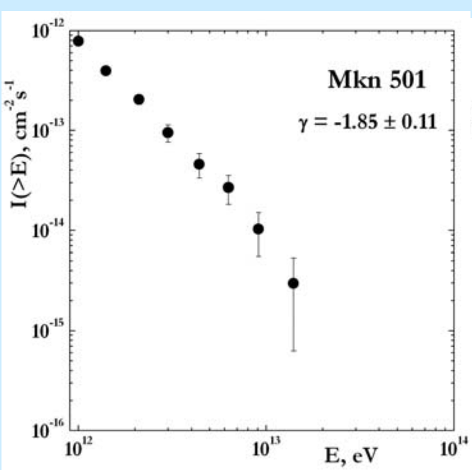


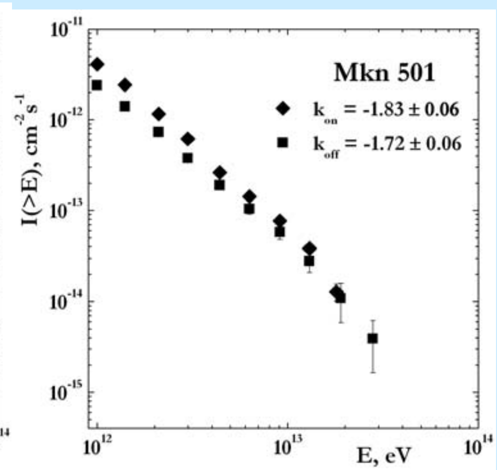


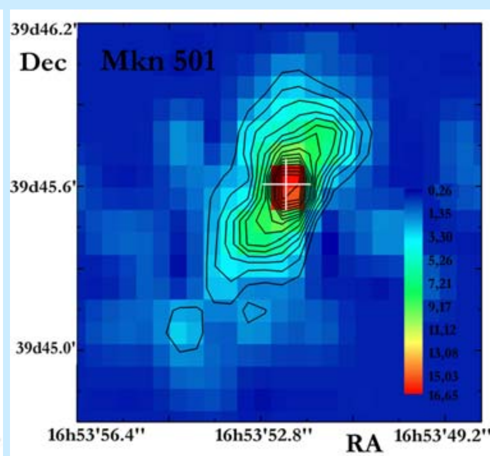
Markarian 501

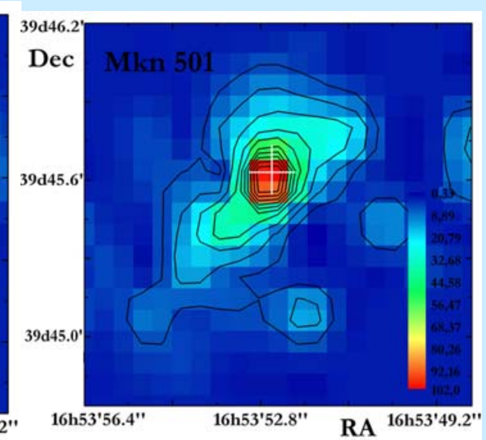


The detection of Mkn 421 as metagalactic VHE gamma-ray source initiated a search for VHE emission from several other active galactic nuclear of blazar type. This led to the detection of BL Lac object Mkn 501 (z = 0.034) by Whipple in 1995. In contrast to Mkn 421, EGRET had not detected this source, as significant source of gamma rays. So Mkn 501 was the first object to be discovered by as gamma-ray source from the ground.. An image of gamma-ray emission from Mkn 501 by SHALON telescope is also shown. The integral average gamma-ray flux above 0.8 TeV was estimated as $(0.86 \pm 0.13)\times 10^{-12}$ cm^{-2}s^{-1} and the power index of the integral spectrum is k_γ==-1.85±0.11. The significant increase of Mkn 501 flux was detected in 1997 with the VHE ground telescopes all over the world. The integral gamma-ray flux in 1997 and 2006 by SHALON telescope was estimated as $(1.21\pm0.13)\times10^{-12}$ cm^{-2}s^{-1} and $(2.05\pm0.23)\times10^{-12}$ cm^{-2}s^{-1}, respectively that is comparable with flux of powerful galactic source Crab Nebula.

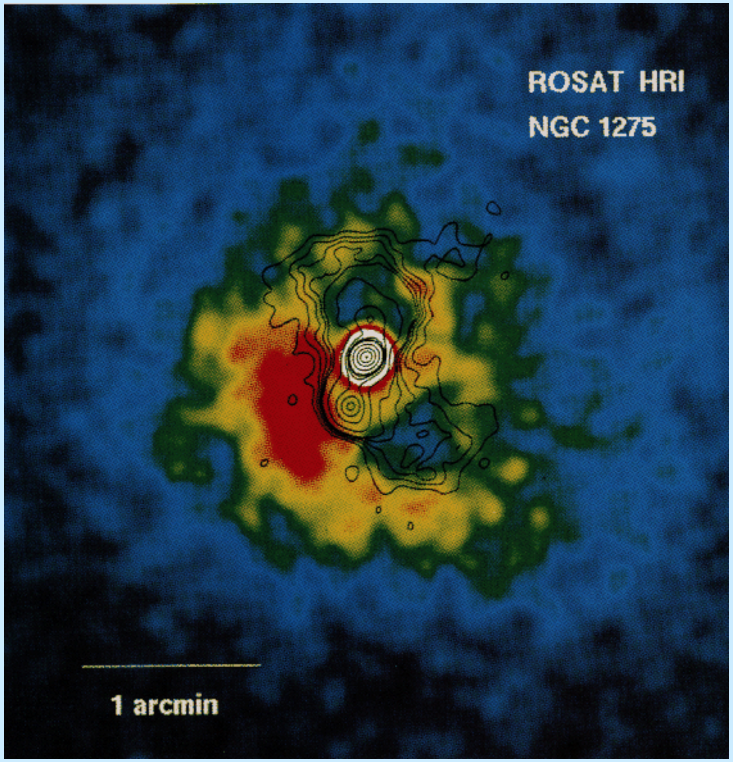




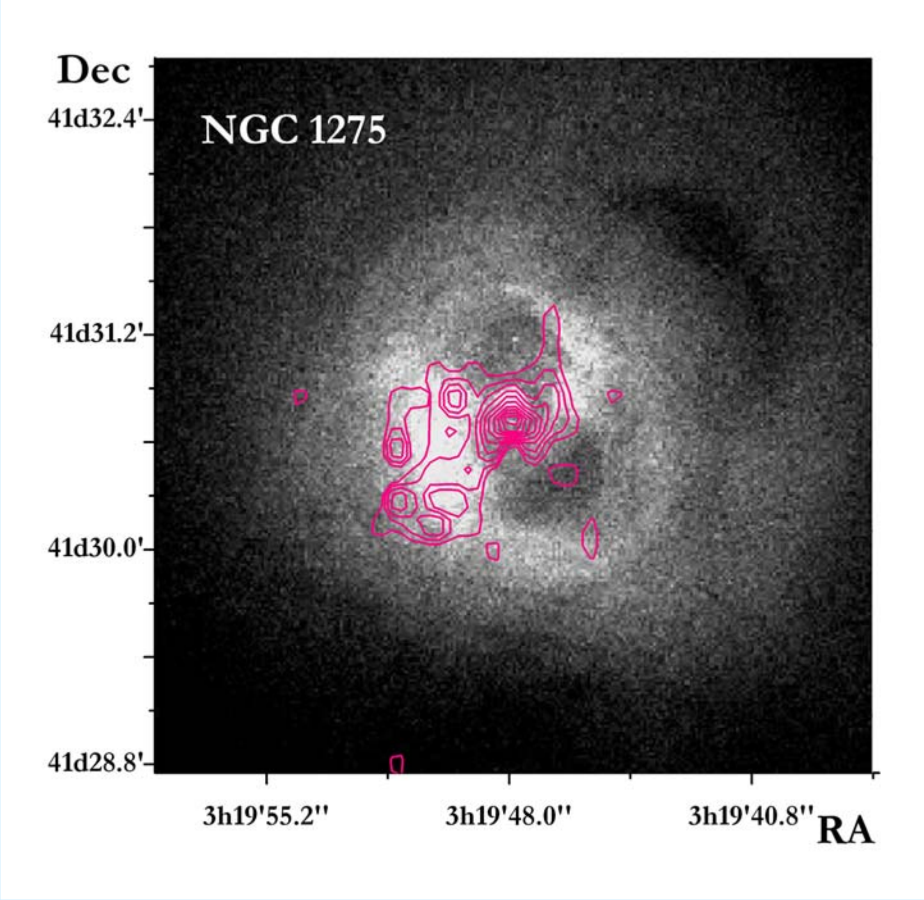




NGC 1275



A ROSAT HRI image of the region around the galaxy NGC 1275 at the centre of the Perseus galaxy cluster. The contour lines show the radio structure as given by VLA observations. The maxima of the X-ray and radio emission coincide with the active nucleus of NGC 1275. In contrast, the X-ray emission disappears almost completely in the vicinity of the radio lobes.



A Chandra X-ray image of NGC 1275 at the centre of the Perseus galaxy cluster.

The contour lines show the TeV - structure by SHALON observations.

NGC 1275

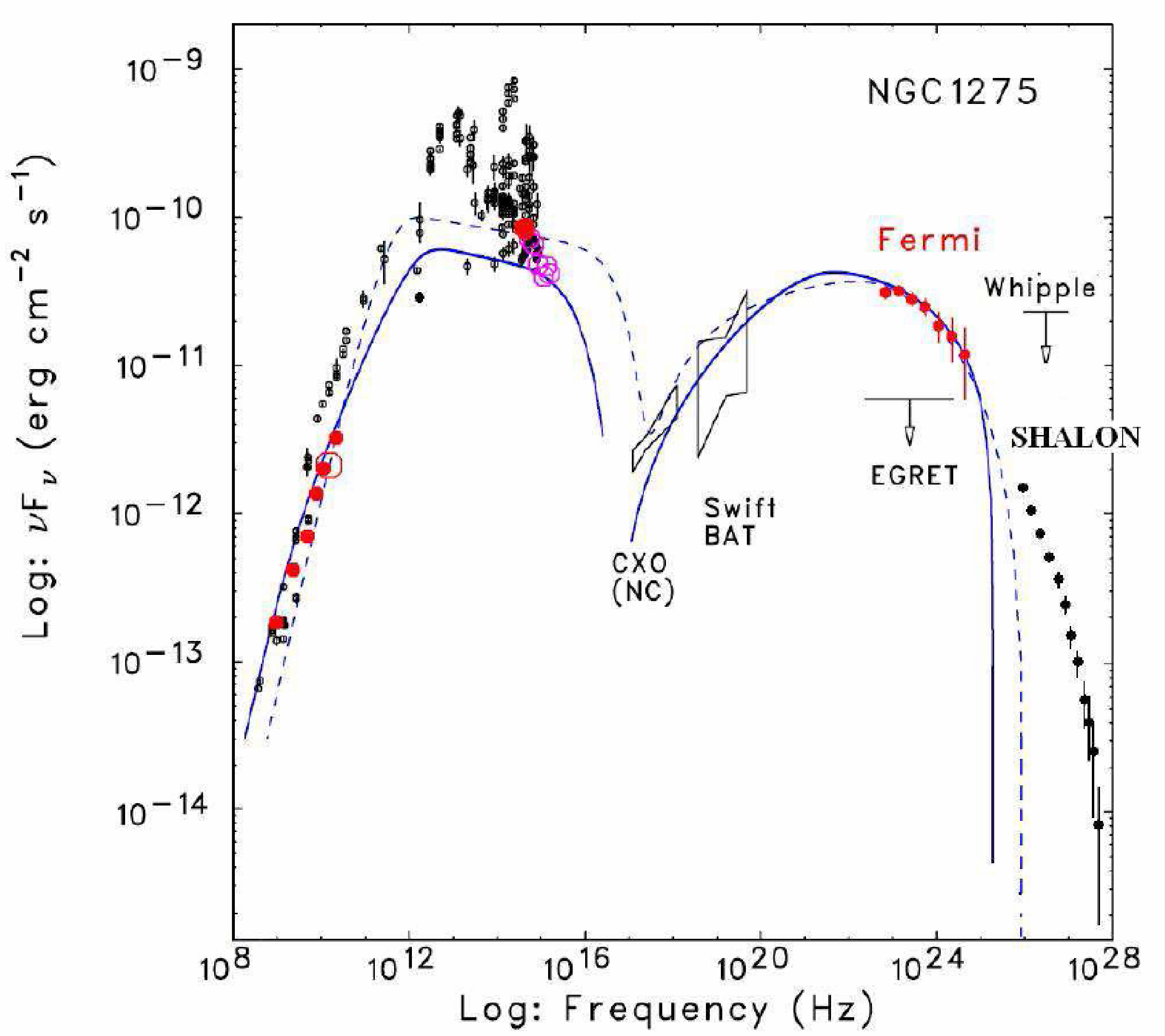
In 1996 year a new metagalactic source are detected by SHALON in TeV energies. This object was identified with Seyfert galaxy NGC 1275 (with redshift z=0.0179); its image is presented. The integral gamma-ray flux for this source is found to be $(0.78\pm0.13)\times10^{-12}\mathrm{cm}^{-2}\mathrm{s}^{-1}$ at energies of > 0.8 TeV.

The Seyfert galaxy NGC 1275 has been also observed with the Tibet Array (about 5 TeV) and then with Veritas telescope at energies about 300 GeV at 2009.

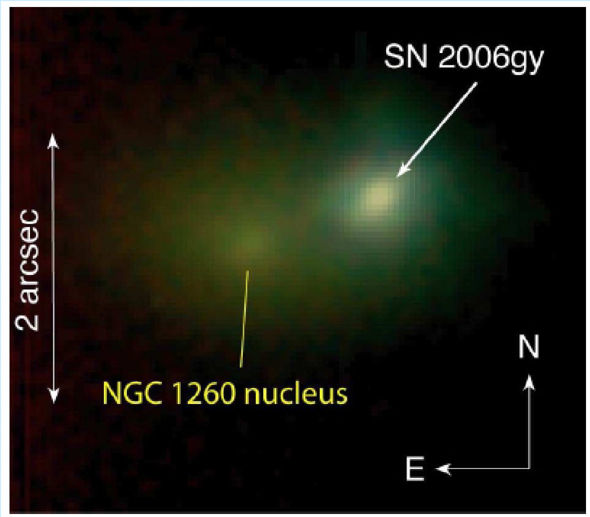
The recent detection by the Fermi LAT of high-energy gamma-rays from the radio galaxy NGC 1275 makes the observation of the very high energy (E > 100 GeV) part of its broadband spectrum particularly interesting.

The overall spectral energy distribution of NGC 1275 from the low energies to the TeV energies is presented.

The spectrum of NGC 1275 from SHALON 15 year observations is also shown.



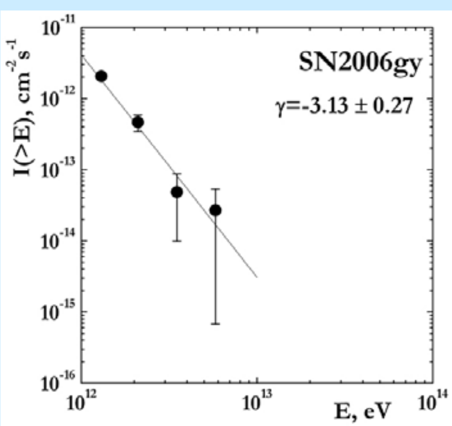
SN2006 gy

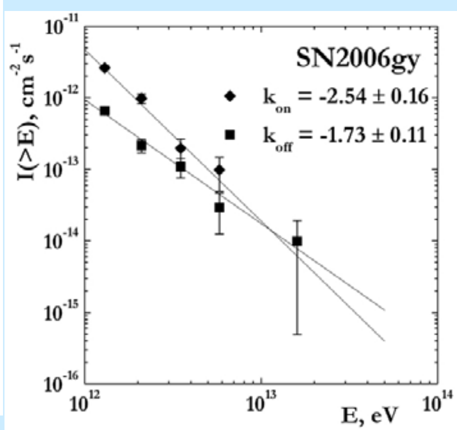


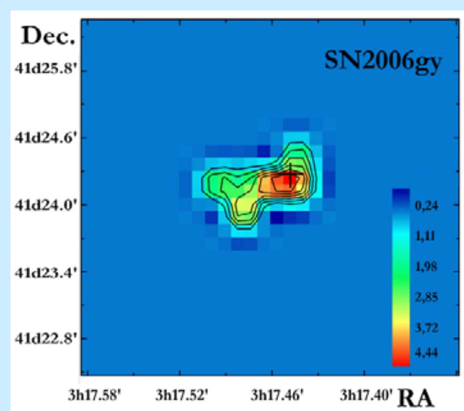
Laser guide star adaptive optics image of SN 2006gy and the nucleus of NGC 1260, showing a clear offset of the SN from the galaxy center. Blue is J band (1.25 μm), green is H band (1.65 μm), and red is Ks band (2.2 μm) on the Shane 3-m telescope at Lick Observatory. [Smith et. all, 2007]

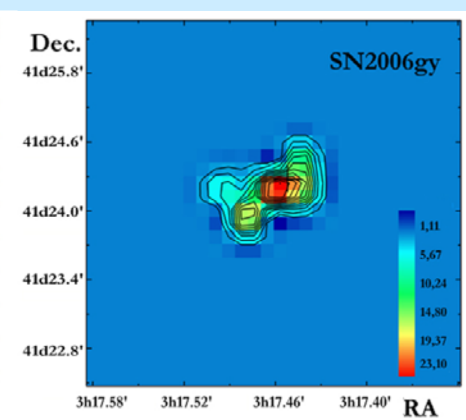
The flux increase was detected from the region NGC 1275 in autumn 2006. The detailed analysis of gamma-shower direction turned out the detection of metagalactic object. This object was identified with the supernova SN 2006gy that is about 10 minutes away from NGC 1275.

Observations had been done in cloudless nights of moonless periods of 2006 Sep., Oct., Nov. Dec. and then during the winter of 2007. No flux increase was found in September observations. In the flare, observed on Oct. 22, the flux increased 6 times from the NGC 1275 and stayed on this level all Oct. moonless period. The integral gamma-ray flux for SN 2006gy is found to be $(3.71\pm0.65)\times10^{-12}$ $cm^{-2}s^{-1}$ at energies of > 0.8 TeV. The energy spectrum of SN2006 gy at 0.8 to 7 TeV can be approximated by the power law $F(>E_O)\propto E^{k\gamma}$, with $k\gamma = -3.13 \pm 0.27$. An images of gamma-ray emission from SN2006 gy by SHALON telescope are presented. Follow-up observations on end of Nov. Showed that the flux of SN2006 gy had dropped to a flux level of about $(0.69\pm0.17)\times10^{-12}$ $cm^{-2}s^{-1}$ and was constant during the Nov. Dec. period. The results of observation analysis of 2007 have no revealed TeV gamma-ray emission from region of SN 2006gy. So, the explosion of extragalactic supernova was observed at TeV energies for the first time with SHALON Cherenkov telescope.



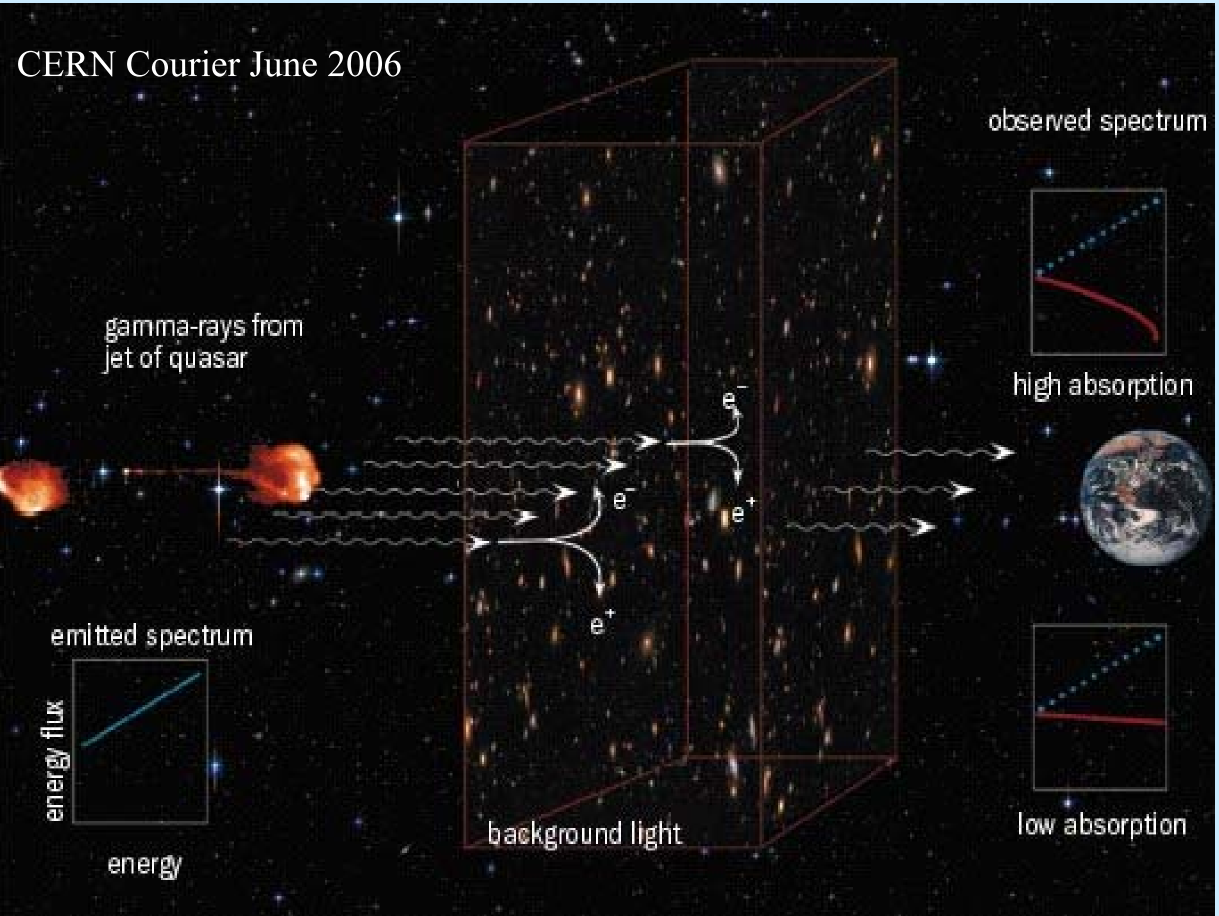






Metagalactic sources of very high energy gamma-quanta

Observations of active galactic nuclei can also be used for the study of Extragalactic Background Light. The light emitted from all objects in the Universe such as stars, galaxies, hot dust etc. during its entire history forms a background light of photons named "diffuse extragalactic background light" (EBL). The EBL spectrum contains an information about star and galaxy formation on early stages of Universe evolution. TeV gamma-rays, radiated by distant sources, mostly interact with IR-photon background via $\gamma+\gamma\rightarrow e^+e^-$ resonant process, then relativistic electrons can radiate gamma-ray with energies less than of primary gamma-quantum. As a result, primary spectrum of gamma-source is changed, depending on spectrum of background light. So, a hard spectra of Active Galactic Nuclei with high red shifts of 1.6 -1.8 allow to determine an absorption by Extragalactic Background Light and thus spectrum of EBL.

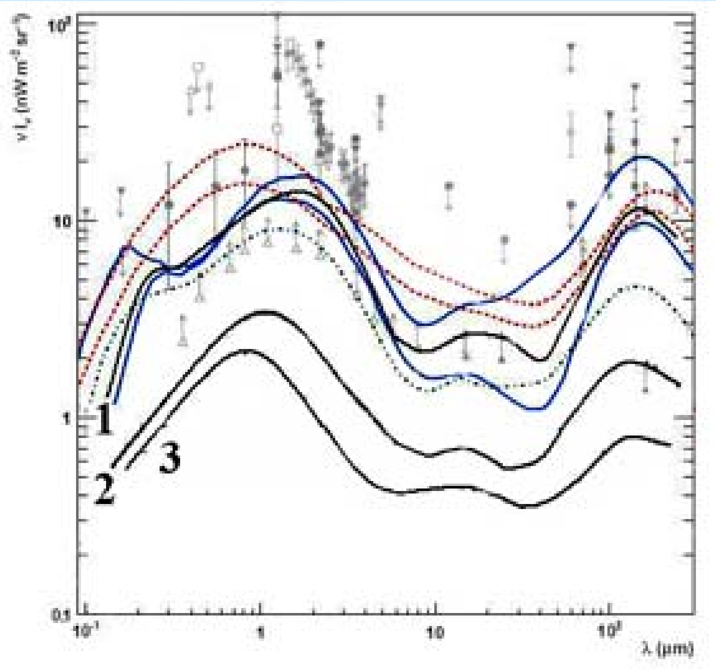


During the period 1992-2010 seven metagalactic sources have been observed:

NGC 1275	**z = 0.0179;**
SN 2006gy	**z = 0.019;**
Mkn 421	**z = 0.031;**
Mkn 501	**z = 0.034;**
Mkn 180	**z = 0.046;**
3c382	**z = 0.0578;**
OJ 287	**z = 0.306;**
3c454.3	**z = 0.859;**
1739+522	**z = 1.375;**

Observations of distant metagalactic sources have shown that the Universe is more transparent to very high energy gamma-rays than previously believed.

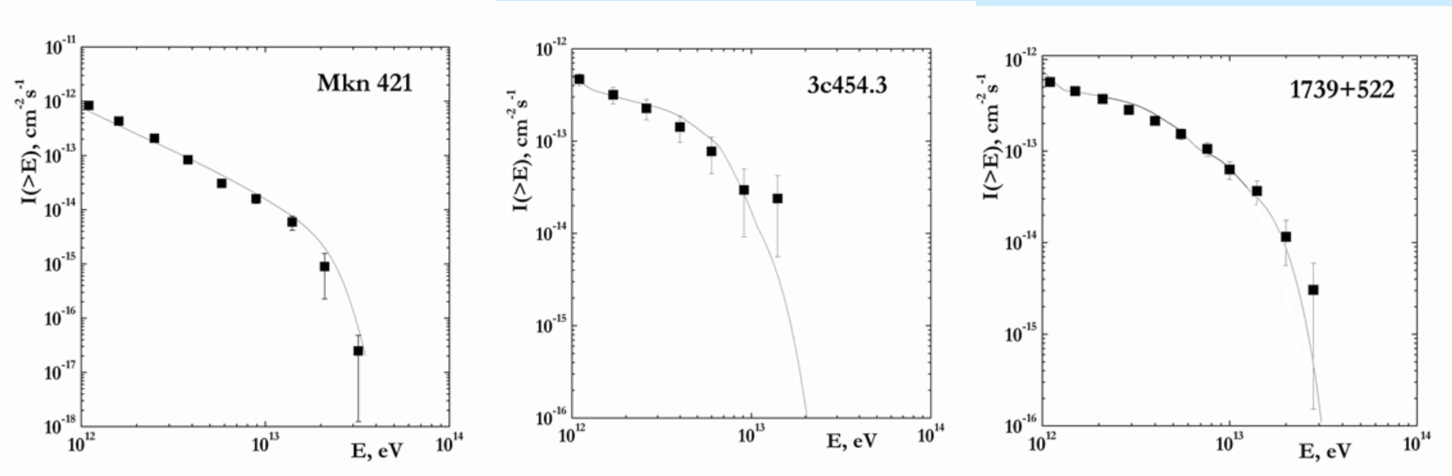
Extragalactic Background Light



It has mentioned that the observed spectra are modified by gamma-ray attenuation, i.e. $F_{observed}(E) = F_{intrinsic}(E) \times exp(\tau\ (E; z))$ where $\tau(E; z)$ is optical depth for pair creation for a source at redshift z, and at an observed energy E. According to the definition of the optical opacity the medium influences on the primary source spectrum at $\tau \geq 1$, but for $\tau < 1$ the medium is transparent, so the measuring of source spectrum in the both range of τ can give the intrinsic spectrum of the source to to constrain the EBL density. The optical depth for sources at redshifts from 0.031 to 1.375 was calculated with assumption of EBL shapes shown in figure left. We used the averaged EBL shape from best-fit model and Low-SFR model [19] (upper black curve) to calculate the attenuated spectrum of Mkn 421 in assumption of simple power low intrinsic spectrum of the source with spectrum index of $\gamma = 1.5$, taken from the range of $\tau < 1$. The result is shown with thin line; the black squares are observational data for Mkn 421.

Spectral energy distribution of EBL: models [17], [19] and measurements [18]; 1 - averaged EBL shape from best-fit model and Low-SFR model [19], 2 - EBL shape from constrained from observations of 3c454.3 (z=0.859); 3 – EBL shape from constrained from observations of 1739+522 (z=1.375)

The shapes of EBL density constrained from the spectra of the high redshift sources 3c454.3 (z=0.859) and 1739+522 (1.375) are shown in fig 5 with curves 2 for and 3, accordingly. For these FSRQ sources the slope of intrinsic spectrum is taken $\gamma = 0.4$. The attenuated spectra for 3c454.3 and 1739+522 are also presented (thin lines) together with observational data. Observations of distant metagalactic sources have shown that the Universe is more transparent to very high-energy gamma-rays than previously believed.



The measured spectra for Mkn 421, 3c454.4 and 1739+522 (black squares) together with spectra attenuated by EBL (lines)

Conclusion

SHALON is taken data since 1992 and the several results from gamma-ray astronomy were presented.

The development of the atmospheric Cherenkov imaging technique has led to significant advances in gamma-ray detection sensitivity in the energy range from 800 GeV to 100 TeV. The SHALON Observatory telescope has detected the galactic and extragalactic sources in the Northern Hemisphere. The gamma-ray sources form a new class of high-energy objects in the Universe, including active galactic nuclei, radio galaxies, galactic binaries, pulsar wind nebulae, in addition to supernova remnants which are assumed to be the origin of cosmic rays for a long time. Exploring the emission mechanism from these objects is a big challenge in astrophysics. Non-thermal nature of emission inherently needs multiwavelength observations to study the phenomena, involving astronomers working in other wavelength.

The spectrum of Crab Nebula observed by SHALON is close to the predicted flux of γ-rays due to Inverse Compton scattering of low energy photons by multi-TeV electrons in the Nebula if the magnetic field of 67 nT in the region responsible for X-ray emission is taken into account.

Tycho's SNR has long been considered as a candidate for a cosmic ray hadron source in the Northern Hemisphere. The detection of gamma-rays at energies 10 - 80 TeV by SHALON provides an evidence of their hadronic origin.

The galactic source CygX-3, has been regularly observed since 1995. Extreme variability in different wavelengths including VHE gamma rays is one of most the distinctive feature of Cygnus X-3 binary system.

The γ-ray spectra and fluxes of known blazars Mkn421, Mkn501 as the spectrum of NGC1275 and distant flat-spectrum radio quasars 1739+522 and 3c454.3 are presented.

Extragalactic diffuse background radiation blocks the propagation of TeV γ-ray over large distances ($z>0.1$) by producing electron-positron pairs. The redshifts of SHALON very high energy γ-ray sources range from $z=0.0183$ to $z=1.375$. Spectral energy distribution of Extragalactic Background Light constrained from observations of Mkn421 (0.031), 3c454.3 ($z=0.859$) and 1739+522($z=1.375$) together with models and measurements are presented. Observations of distant metagalactic sources have shown that the Universe is more transparent to very high-energy γ-rays than previously believed.